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Burial Experiments on Marine Pelecypods from Tomales Bay, California

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INTRODUCTION

BURIAL EXPERIMENTS and the after-effects on *Tellina salmonea, Tellina buttoni,* and *Transennella tantilla* have not as yet been reported. The harmful effects of high concentrations of particulate matter and microorganisms to filtering and feeding in bivalves have been investigated by many. For example, LOOSANOFF & ENGLE (1940, 1947), LOOSANOFF & TOMMERS (1948), CHIPMAN & HOPKINS (1954), BALLENTINE & MORTON (1956), CHIBA & OHSHIMA (1957), LOOSANOFF (1962), and ARMSTRONG (1965) have all been concerned with various aspects of this problem.

In a field study MAURER (1966) described some pelecypod-sediment associations in Tomales Bay, California. The author concluded that distribution and abundance of *Tellina buttoni* DALL, 1900, *Tellina salmonea* (CARPENTER, 1864), *Mysella tumida* (CARPENTER, 1864), and *Lyonsia californica* CONRAD, 1837 were influenced by sediment type, while that of *Transennella tantilla* (GOULD, 1852) were not. Furthermore it was shown that the average size of *Tellina buttoni, Tellina salmonea,* and *Mysella tumida* was statistically associated with sediment size. No conclusions were drawn as to the biological significance of sediment to mollusks in terms of food, protection, larval sites, and certain conditions of turbidity.

In order to interpret the pelecypod-sediment relationships and to determine the importance of sediment to mollusks some filtering experiments were performed (MAURER, 1967). *Transennella tantilla* combined the highest filtering rate with the least apparent difficulty in filtering suspensions of carmine, kaolinite, and india ink particles. *Tellina salmonea* had the lowest clearing rate and had far less difficulty ingesting and digesting the suspensions than *Tellina buttoni* which had a relatively high filtering rate, but commonly became filled with particles from the suspensions. Results of these experiments suggested that sediment may represent a source of food or a certain turbidity regime.

Workers differ in opinion concerning the effects of turbidity on pelecypods. For example, TURNER (1953) noted in contrast to LOOSANOFF & ENGLE (1947) that the hard clam *Venus mercenaria* (LINNAEUS, 1758) differs from the oyster in that the former can utilize *Chlorella* and green flagellates even in concentrations so dense that the water is soupy green. However, a study of *V. mercenaria* by RICE & SMITH (1958) demonstrated that addition of silt to algal suspensions resulted in an instantaneous decrease in the filtering rate of the clam. Moreover, the clams formed large quantities of pseudofeces in the presence of high concentrations of algae, in all suspensions of *Chlorella,* and after silt was added. With this in mind, the present investigation examined the survivorship of clams buried under different amounts of clay for different periods of time. Also their rate of recovery after being placed in clean sand with rapidly flowing sea water was recorded. Results of these experiments show that mortalities and production of feces and pseudofeces were greatest in the heaviest loads of clay and that *Transennella tantilla* suffered fewer mortalities than *Tellina salmonea,* which suffered still fewer mortalities than *Tellina buttoni.*

METHOD

The general method was as follows: *Tellina buttoni, T. salmonea* and *Transennella tantilla* were suspended by a screen 3.0 cm above the bottom of a 1000 ml beaker. A set of pelecypods was formed which consisted of a group of the three species each in its own beaker. Except for experiment 1 every experiment had three sets of pelecypods.

Clay was gently poured into a beaker and allowed to settle undisturbed. In general, clay was introduced at the beginning of an experiment, although in experiment 2 a given amount of clay was added to each set at hourly intervals for 10 hours. Two types of clay, montmorillonite and kaolinite, were used, the former only in experiment 1 and the latter in experiments 2 through 6. Montmorillonite and kaolinite are common clay minerals in muds of bays and estuaries and provide some basis for comparison with mud in a natural situation.

The sets of clams were buried under different amounts of clay for different periods of time. This was done to obtain some estimate as to the cumulative effect on mollusks of increased loads of clay with an increased period of burial. Amount of clay was generally separated into three categories so that the three sets of bivalves were buried under three different loads or groups of clay. The loads ranged from 10 to 20 g in experiment 1, 10 to 20 to 30 g in experiment 2, and 10 to 30 to 50 g in experiments 4 through 6. Experiment 3 contained a control or no kaolinite group with 2 groups of 50 and 100 g. Elapsed burial time ranged from 5 hours to 31.5 hours with the majority of experiments varying from 24 to 30 hours.

At the end of the burial periods sets of clams were unearthed from the clay and placed on top of clean sand in beakers of sea water. A continuous flow of water was supplied. Survivorship was recorded as well as burrowing and siphonal activity to assess the general condition of the pelecypods. Dead clams were easy to distinguish from live ones as the former were always agape. Following the disinterment similar observations were noted at various intervals. Finally the experiment was terminated and dissections were performed on the test mollusks.

RESULTS

The number of clams buried, the number dead and alive when they were unearthed, and the number dead and alive after a period in clean sea water, are listed in Table 1. The relative amount of clay found in the mantle cavity and the occurrence of feces and pseudofeces associated with each species are summarized in Table 2.

Experiment 1: After 5 hours of burial the specimens were all alive when they were unearthed. *Transennella tantilla* in the 10 and 20 g groups responded immediately to clean sea water by burrowing and extending their siphons. Almost 12 hours after *Tellina salmonea* from the 20 g group had been uncovered, two individuals were still on the surface of the sand and one specimen had died. During this period the majority of these mollusks burrowed into the sand and were actively waving their siphons in the water. *Tellina buttoni* showed a gradual response to being uncovered and placed in clean sea water, as 15 hours after they were unearthed all the bivalves in the 10 g group and 9 members of the 20 g group had burrowed. Information from dissections indicated that *Tellina buttoni* contained more clay than either *T. salmonea* or *Transennella tantilla,* both of which were relatively clean. Although *Tellina salmonea* sustained one mortality, this tellinid and *Transennella tantilla* were less adversely affected by the experiment than *Tellina buttoni.*

Experiment 2: Elapsed burial time was 24 hours and this was the only experiment in which clay was added at hourly intervals for many hours. When *Transennella tantilla* was removed from the clay, it responded immediately to clean sea water by burrowing and extending its siphons. Within 10 to 15 minutes after being uncovered *Tellina buttoni* began to revive and *T. salmonea* began to respond after 30 minutes. Five hours after *Tellina salmonea* had been removed from the clay all test animals had revived except two individuals from the 20 g group. The two mortalities and the relatively slow rate of recovery indicated that *Tellina salmonea* had the most difficult time withstanding the hourly loads of clay. *Transennella tantilla* and *Tellina buttoni* survived the experiment about equally well.

Experiment 3: Elapsed burial time was about 31.5 hours and when the specimens were uncovered, they were all alive. Sixteen hours later one each of *Tellina buttoni* and *Transennella tantilla* from the control beakers were dead, 5 *Tellina buttoni* and 2 *Transennella tantilla* were dead in the 50 g group, and 3 *Tellina buttoni* and 2 venerids were dead in the 100 g group. *Tellina salmonea* and *Transennella tantilla* appear to have been less affected by the clay and responded more rapidly to the sea water than *Tellina buttoni.* Although 5 *Transennella tantilla* died during the experiment its recovery rate and lack of clay ingestion indicated that the small venerid was second in survivorship for this experiment.

Experiment 4: Elapsed burial time was 28.5 hours and after this period 5 *Tellina buttoni* in the 30 and 50 g groups were dead. About 2 hours after the mollusks had

Table 1

Summary of Burial Experiments 1 through 6.
Results expressed as number of live (L) and dead (D) clams after burial period and during periods of revival.

Cumulative Elapsed Time	hr:min	*Tb*	*Ts*	*Tt*	*Tb*	*Ts*	*Tt*	*Tb*	*Ts*	*Tt*
1. Montmorillonite		10 grams			20 grams			30 grams		
Buried	00:00	10L	10L	10L	8L	10L	10L			
Unearthed	05:00	–	–	–	–	–	–			
Revival	16:45	–	–	–	–	9L-1D	–			
Revival	89:00	10L	10L	10L	8L	9L-1D	10L			
2. Kaolinite		One, two, and three grams at hourly intervals for ten hours								
Buried	00:00	4L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	24:00	–	–	–	–	–	–	–	–	–
Revival	29:00	4L	10L	10L	5D	8L-2D	10L	5L	10L	10L
3. Kaolinite		Control (no Kaolinite)			50 grams			100 grams		
Buried	00:00	5L	10L	10L	5L	10L	10L	3L	8L	10L
Unearthed	31:25	–	–	–	–	–	–	–	–	–
Revival	47:10	4L-1D	10L	9L-1D	5D	10L	8L-2D	3D	8L	8L-2D
4. Kaolinite		10 grams			30 grams			50 grams		
Buried	00:00	5L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	28:30	–	–	–	5D	–	–	5D	–	–
Revival	30:15	4L-1D	–	–	–	–	–	–	–	–
Revival	41:00	3L-2D	10L	10L	5D	10L	10L	5D	4L-6D	10L
5.										
Buried	00:00	5L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	29:15	–	–	–	–	–	–	–	–	–
Revival	41:15	4L-1D	10L	10L	5D	10L	10L	5D	10L	9L-1D
6.										
Buried	00:00	5L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	24:00	–	–	–	–	–	–	–	–	–
Revival	30:00	5L	8L-2D	10L	4L-1D	7L-3D	9L-1D	2L-3D	8L-2D	10L

Tb = *Tellina buttoni*, *Ts* = *Tellina salmonea*, *Tt* = *Transennella tantilla* been unearthed, 1 *T. buttoni* from the 10 g group had died. During the final 10 hours of the experiment another *T. buttoni* in the 10 g group and 6 *T. salmonea* in the 50 g group died. *Transennella tantilla* survived the experiment in good condition and upon dissection was found to contain less clay material than *Tellina salmonea* or *Tellina buttoni*. The former tellinid finished the experiment in better condition than the latter.

Experiment 5: Elapsed burial time was approximately 29 hours, and all the sets were alive when they were uncovered. Twelve hours later 1, 5, and 5 specimens of *Tellina buttoni* had died in the three clay groups respectively, while 1 *Transennella tantilla* in the 50 g group died. *Tellina salmonea* survived the experiment slightly better than *Tr. tantilla* and both species fared considerably better than *Tellina buttoni*.

Experiment 6: In the last experiment elapsed burial time was 24 hours and all the sets survived the burial period. Six hours after *Tellina salmonea* had been uncovered, 2, 3, and 2 specimens respectively had died. Three *Tellina buttoni* in the 50 g group and 1 each of *T. buttoni* and *Transennella tantilla* in the 30 g group had died during the same period.

DISCUSSION

Maurer (1967) cautioned against placing undue reliance on the comparative results of filtering experiments, unless similar ctenidial and feeding types were compared. The same warning applies to the present research.

The ctenidial structure of the tellinids and of *Transennella tantilla* are different and the pelecypods are reputed to feed differently. For example, the size of the ctenidia in the tellinids is reduced in comparison with the size of the labial palps, whereas in *Transennella tantilla* the palps are relatively minor features compared with its ctenidia. *Transennella tantilla* is probably a suspension feeder and the tellinids have been considered deposit feeders (Yonge, 1949). Nevertheless, more and more evidence is accumulating on the mode of feeding of *Tellina salmonea* and *T. buttoni* that these tellinids may not be restricted to one mode of feeding. Thus it is not surprising, given different modifications in ctenidial structures and more complex feeding behavior, that their response to the effect of heavy loads of clay should be very different.

Among the three species, *Transennella tantilla* most successfully survived the burial experiments as only 7 individuals out of 170 specimens died (Table 1). Six of the mortalities occurred under the influence of the heavier clay loads. When *Tr. tantilla* was placed in clean sea water, its response (burrowing, siphonal activity, excretory function) was almost immediate, and in general, individuals rarely contained much clay. The venerid also produced more feces and pseudofeces than the 2 tellinids (Table 2). This indicated that it was able to ingest the clay, process it through the alimentary tract, and form some fecal pellets. Correspondingly with increased loads of clay it was able to withstand the added sedimentation by rejecting material in the form of pseudofeces.

It appears that marked survivorship of *Transennella tantilla* under muddy conditions of burial, and its renewed activity in clean sand and fresh sea water, are in accord with the high filtering rate and ease of digestion recorded earlier from filtering experiments (Maurer, 1967). These data support the view that *Tr. tantilla* can tolerate a variety of sediment types and the turbid conditions raised particularly during deposition of fine sand and mud. Based on tolerance to turbidity it would be expected to find *Tr. tantilla* living in sediment that ranges in particle size from mud to coarse sand.

Interpretation of experimental evidence for the tellinids is not as clear cut. For example, *Tellina salmonea* was relatively successful in surviving the loads of clay as 16 individuals out of 168 specimens died and 14 of these occurred in heavier loads. Although its rate of filtering was relatively low in the filtering experiments, it inhaled and processed suspensions with far greater facility than *T. buttoni* (Maurer, 1967). From its optimal development in clean, medium to coarse sand (Maurer, 1966), it would be expected that burial in clay would be extremely harmful to *T. salmonea*. In the burial experiments its response to clean sand and fresh sea water was the slowest among the species, yet its number of mortalities was considerably less than that of *T. buttoni* and only twice that of *Transennella tantilla*. In addition, results of dissection showed that *Tellina salmonea* was rarely full of clay and that it did produce some feces and pseudofeces. This indicates its ability to inhale and digest fine material in turbid water at least for the limited periods defined by the experimental design. *Tellina salmonea* has been collected from turbid conditions by Reish (1961), but it is a site where this tellinid is not best represented. Again information on mode of feeding might explain the apparent inconsistency between its preferred distribution in coarse sand and its ability to withstand turbid conditions not usually a part of that sedimentary regime.

Tellina buttoni survived the experiment in very poor condition as 36 out of 90 individuals died and 32 of these deaths were again in the heavier loads. Even though *T. buttoni* had a relatively high clearing rate, it had difficulty inhaling and digesting the suspensions used in the filtering experiments (Maurer, 1967). From its optimal development in fine sand with some organic material (Maurer,

Table 2

Relative Amount of Clay found in Clams and the Occurrence of Feces and Pseudofeces for Experiments 1 through 6

1. Montmorillonite	10 grams	20 grams	30 grams
Tellina buttoni	**	** F	
Tellina salmonea	* F	*	
Transennella tantilla	–	–	
2. Kaolinite One, two and three grams at hourly intervals for 10 hours.			
Tellina buttoni		Unexamined	
Tellina salmonea		Unexamined	
Transennella tantilla	P	P	P
3. Kaolinite	Control (no Kaolinite)	50 grams	100 grams
Tellina buttoni	–	*** P	*** P
Tellina salmonea	–	* P	** P
Transennella tantilla	– P	** P	Unexamined
4. Kaolinite	10 grams	30 grams	50 grams
Tellina buttoni	*	**	***
Tellina salmonea	*	**	***
Transennella tantilla	–	* P&F	* P&F
5.			
Tellina buttoni	–	****	****
Tellina salmonea	* F	**	*
Transennella tantilla	–	–	*
6.			
Tellina buttoni	* F	* F	***
Tellina salmonea	– F	*	**
Transennella tantilla	– F	**	**

– = clean; * = trace; ** = small; *** = moderate; **** = heavy; F = feces; P = pseudofeces

1966), it would seem that burial in clay would be less harmful to *T. buttoni* than to *T. salmonea*. Still, in the burial experiments it experienced greatest mortalities, commonly became filled with clay, and produced the least amount of feces and pseudofeces. The amount of clay found in these clams during dissections indicated that they were unable to pass the clay easily through their digestive system, and as a result, they eventually became packed and died. Combination of heavy loads of clay with a specific mode of feeding might explain its inability to cope with the unnatural conditions of sedimentation encountered in the laboratory. Thus, experimental evidence does not, at present, indicate the reason or reasons for the observed preference of *Tellina buttoni* for fine sand.

In conclusion, burial experiments have shown that the number of mortalities and the production of feces and pseudofeces increased as the burial load was increased for all species. *Transennella tantilla* had the smallest number of mortalities and was best able to cope with the turbid conditions of the experiments. Survivorship rate and condition of *Tellina salmonea* and *Tellina buttoni* followed in that order. Results of filtering and burial experiments supply added evidence to further elucidate the occurrence of *Transennella tantilla* in a variety of sediment types. On the other hand, aside from the sediment as a source of food and a possible turbidity regime, experimental data do not presently provide an explanation for the more restricted sediment preference of the tellinids.

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